

What is claimed is:

1. An improved echo control system of the type including:
    - an echo-containing near signal input;
    - an echo canceller, coupled to a far signal reference, producing an echo estimate signal output representative of the echo contained in the near signal;
    - a signal coupling node, coupled to the near signal input and the echo estimate signal output, producing an echo-canceled signal output having an echo residue;
    - an echo shaping filter, coupled to the echo-canceled signal output, reducing the echo residue and providing an echo-suppressed signal output, the echo shaping filter having a spectral response determined by filter coefficients; and
    - a background filter, coupled to:
      - (a) an error signal representative of the difference between:
        - (i) the echo canceled signal, and
        - (ii) a signal representative of background filter spectral response, and
      - (b) an adaptive control module producing a reference signal output that is a weighted sum of:
        - (i) the echo-containing signal, and
        - (ii) the echo canceled signal,
- the background filter updating the filter coefficients of the echo shaping filter responsive to a normalized least mean square (NLMS) algorithm;
- wherein the improvement comprises:
- determining, in the adaptive control module, a reference signal weight for the weighted sum, the weight being proportional to the far signal reference;

and an estimate of the norm of an echo canceller error vector, and  
 inversely proportional to an estimate of a residue of the echo canceller;  
 and

using a non-linear normalized convergence term in the NLMS algorithm.

2. An improved echo control system according to claim 1, wherein the echo canceller is a finite impulse response (FIR) filter.
3. An improved echo control system according to claim 1, wherein the echo shaping filter is a finite impulse response (FIR) filter.
4. An improved echo control system according to claim 1, wherein the background filter is a finite impulse response (FIR) filter.

5. An improved echo control system according to claim 1, wherein the echo canceller error vector is determined as:

$$\Delta w(k) = \mathbf{w}_{ep} - \mathbf{w}(k)$$

where  $\Delta w(k)$  represents the echo canceller error vector,  $\mathbf{w}_{ep}$  represents a physical echo path identified by the echo canceller, and  $\mathbf{w}(k)$  the echo canceller response.

6. An improved echo control system according to claim 1, wherein the reference signal weight is determined as:

$$\alpha(k) = \frac{\beta \|\Delta \mathbf{w}(k)\| \bar{x}_s(k)}{\bar{e}_s(k)}$$

where  $\alpha(k)$  represents the reference signal weight,  $\beta$  represents a constant normalizing term,  $\|\Delta \mathbf{w}(k)\|$  represents an estimate of the norm of the echo canceller error vector,

$\bar{x}_s(k)$  represents a short-term average magnitude of the far signal reference, and  $\bar{e}_s(k)$  represents a short-term average magnitude of the echo canceller residue.

7. An improved echo control system according to claim 6, wherein the echo canceller error vector is determined as:

$$\frac{N + N_T}{N_T} \sum_{i=1}^{N_T} |w_i(k)|$$

8. An improved echo control system according to claim 1, wherein the NLMS update algorithm is:

$$\mathbf{h}(k+1) = \mathbf{h}(k) + \frac{\mu}{\zeta + \mathbf{z}(k)^T \mathbf{z}(k)} \mathbf{z}(k) e_h(k)$$

where  $\mathbf{h}(k)$  represents the echo shaping filter having an order  $L_H$ ,  $\mathbf{z}(k)$  represents a vector representing the  $L_H$  most recent values of the reference signal output,  $e_h(k)$  represents the error signal,  $\zeta$  represents a non-negative constant, and

$\frac{\mu}{\zeta + \mathbf{z}(k)^T \mathbf{z}(k)}$  represents a normalized convergence coefficient.

9. An improved method of echo control of the type including:  
 providing an echo-containing near signal input;  
 producing, with an echo canceller coupled to a far signal reference, an echo estimate signal output representative of the echo contained in the near signal;  
 producing, with a signal coupling node coupled to the near signal input and the echo estimate signal output, an echo-canceled signal output having an echo residue;

reducing, with an echo shaping filter coupled to the echo-canceled signal output, the echo residue and providing an echo-suppressed signal output, the echo shaping filter having a spectral response determined by filter coefficients; and

providing a background filter, coupled to:

- (a) an error signal representative of the difference between:
  - (i) the echo canceled signal, and
  - (ii) a signal representative of back ground filter spectral response, and
- (b) an adaptive control module producing a reference signal output that is a weighted sum of:

- (i) the echo-containing signal, and
  - (ii) the echo canceled signal,
- the background filter updating the filter coefficients of the echo shaping filter responsive to a normalized least mean square (NLMS) algorithm;

wherein the improvement comprises:

determining, in the adaptive control module, a reference signal weight for the weighted sum, the weight being proportional to the far signal reference; and an estimate of the norm of an echo canceller error vector, and inversely proportional to an estimate of a residue of the echo canceller; and

using a non-linear normalized convergence term in the NLMS algorithm.

10. An improved echo control method according to claim 1, wherein the echo canceller is a finite impulse response (FIR) filter.

11. An improved echo control method according to claim 1, wherein the echo shaping filter is a finite impulse response (FIR) filter.
12. An improved echo control method according to claim 1, wherein the background filter is a finite impulse response (FIR) filter.
13. An improved echo control method according to claim 1, wherein the echo canceller error vector is determined as:

$$\Delta w(k) = \mathbf{w}_{ep} - \mathbf{w}(k)$$

where  $\Delta w(k)$  represents the echo canceller error vector,  $\mathbf{w}_{ep}$  represents a physical echo path identified by the echo canceller, and  $\mathbf{w}(k)$  the echo canceller response.

14. An improved echo control method according to claim 1, wherein the reference signal weight is determined as:

$$\alpha(k) = \frac{\beta \|\Delta \mathbf{w}(k)\| \bar{x}_s(k)}{\bar{e}_s(k)}$$

where  $\alpha(k)$  represents the reference signal weight,  $\beta$  represents a constant normalizing term,  $\|\Delta \mathbf{w}(k)\|$  represents an estimate of the norm of the echo canceller error vector,  $\bar{x}_s(k)$  represents a short-term average magnitude of the far signal reference, and  $\bar{e}_s(k)$  represents a short-term average magnitude of the echo canceller residue.

15. An improved echo control method according to claim 6, wherein the echo canceller error vector is determined as:

$$\frac{N + N_T}{N_T} \sum_{i=1}^{N_T} |w_i(k)|$$

16. An improved echo control method according to claim 1, wherein the NLMS update algorithm is:

$$\mathbf{h}(k+1) = \mathbf{h}(k) + \frac{\mu}{\zeta + \mathbf{z}(k)^T \mathbf{z}(k)} \mathbf{z}(k) e_h(k)$$

where  $\mathbf{h}(k)$  represents the echo shaping filter having an order  $L_H$ ,  $\mathbf{z}(k)$  represents a vector representing the  $L_H$  most recent values of the reference signal output,  $e_h(k)$  represents the error signal,  $\zeta$  represents a non-negative constant, and

$\frac{\mu}{\zeta + \mathbf{z}(k)^T \mathbf{z}(k)}$  represents a normalized convergence coefficient.